# MONITORING STOCKS OF CONCERN IN PINE CREEK

Hoopa Valley Tribal Fisheries Dept.

FINAL REPORT

AGREEMENT # 14-48-001-96

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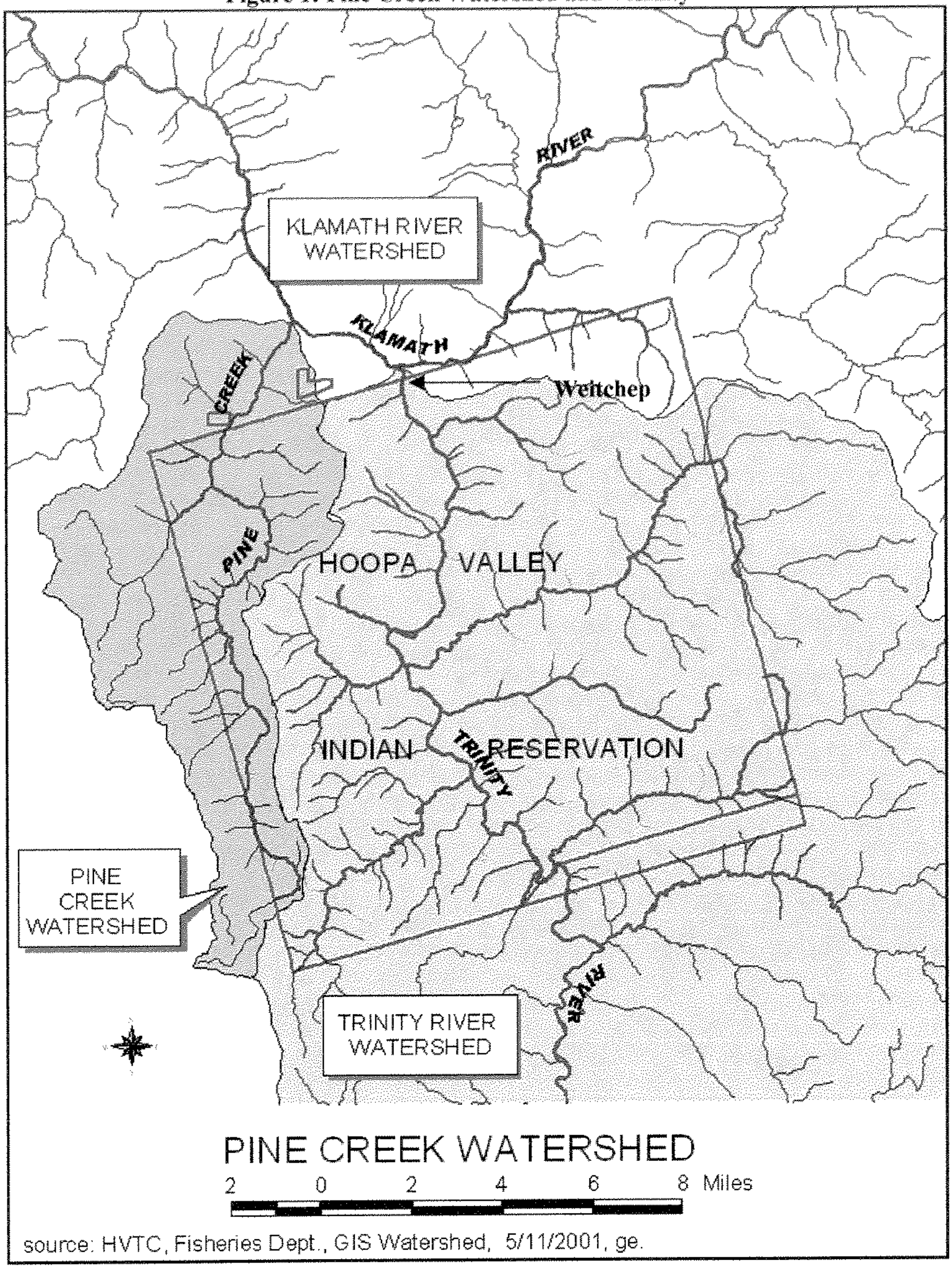
**Abstract**

In 1995, the National Marine Fisheries Service (NMFS) concluded that it intended to list steelhead of the Klamath Mountains Province (KMP) as a threatened species under the Endangered Species Act (Federal Register Notice, Vol. 60. No. 51, 16 [March 1995]). At that time, NMFS had failed to find any evidence of naturally self-sustaining steelhead populations within the KMP. Pine Creek is a major drainage within the Klamath basin, and once provided ideal habitat for steelhead and other anadromous salmonids. Past land management has compromised Pine Creek's juvenile salmonid output. The objective of this project was to monitor fish and habitat restoration efforts to assess the relative success of restoration prescriptions conducted within the Pine Creek drainage. In-stream sampling was conducted to index the abundance of juvenile salmonids within the Pine Creek watershed. Adult escapement was monitored with periodic spawner/redd surveys in reaches of Pine Creek. A sediment recruitment study was also conducted.

Numbers of juvenile outmigrants in 1996 were compared to data collected prior to and after 1996 (pre- and post-restoration efforts). The results indicated that 17, 1, 0 and 14 redds were observed in 1997, 1998, 1999, and 2000 sample seasons, respectively. The average redd size was 28.52 $ft^2$ at an average depth of 1.19 ft. The average substrate composition was 19% sand, 38% gravel, 39% cobble, and 5% boulder. The preferred habitat type was *Run*. No spawner survey data was available from 1990-1996 for trend analysis. Steelhead was the most abundant of three species examined. Steelhead had the highest CPUE (catch per day), and steelhead redds comprised at least 67% of all redds documented. There were no inter-annual trends in CPUE (catch per day) in fyke nets for chinook, coho, or steelhead when examining pre-restoration (1992-1995) and post-restoration (1996-2001) time periods. Of the three species, only steelhead may serve as a proper indicator species and only steelhead CPUE showed a significant increase in the post-restoration period. Each species' CPUE became significantly more variable in the post-restoration period. If factors other than chronic sediment delivery were now limiting production in Pine Creek stocks, it could explain the increased variability in CPUE. Whatever the cause of the increased variability, it considerably masks detection of increases in juvenile outmigration as a function of restoration efforts.

Sediment quality was measured at potential spawning sites both upstream and downstream from the influence of the watershed restoration efforts, both pre-project and post-project. The mean percentage of fine sediment decreased at all sites from 1994 (pre-project) to 2000 (post-project), indicating a general increase in the quality of surface material as spawning gravel in riffles and pool tail crests in Pine Creek. This decrease is not significant, however, at a 95% confidence level. Though restoration efforts may be responsible for this decrease in fine sediment, it is likely that the flushing effect from a large 1997 storm was at least equally responsible.

**Figure 1: Pine Creek Watershed and Vicinity**



**Introduction**

Pine Creek is a major drainage within the Klamath basin that once provided ideal habitat for steelhead and other anadromous salmonids. Past land management was suspected to have compromised Pine Creek's juvenile salmonid output and adult spawning population. Forty percent of the 31,426 acre Pine Creek watershed lies within the boundaries of the Hoopa Valley Indian Reservation. The Hoopa Valley Tribe committed to watershed restoration efforts in Pine Creek in 1990. Work completed since 1984 includes a watershed assessment and itemized prescriptions for problem areas within the sub-basin, and fish and habitat monitoring. Habitat rehabilitation work—initiated by the Hoopa Valley Tribe in the four years (1992-1996) preceding this project—sought to complement restoration work with a comprehensive fish and habitat monitoring program. This program was designed to gather evidence relative to the efficacy of prescribed land treatments in restoring usable habitat for steelhead and other anadromous species within the Pine Creek watershed.

To complement the restoration work, the Tribe also completed four years of fish and habitat monitoring within the Pine Creek Drainage (1992-1996). Monitoring fish populations and habitat was intended to demonstrate the relative improvement in anadromous fishery resources and habitat conditions in response to restoration efforts. Monitoring has included fyke-trap juvenile sampling for species identification and relative abundance estimates. Fall chinook and steelhead spawning escapement surveys have also been conducted during the months of November-February.

In 1995, the National Marine Fisheries Service (NMFS) concluded that it intended to list steelhead of the Klamath Mountains Province (KMP) as a threatened species under the Endangered Species Act (Federal Register Notice, Vol. 60. No. 51, 16 [March 1995]). NMFS had failed to find any evidence of naturally self-sustaining steelhead populations with the KMP. The prospects of that listing enhanced the importance of this research.

Sediment particle distribution was analyzed as an indicator of sediment recruitment. Specifically, spawning gravel was analyzed for this task. Both chinook salmon and steelhead trout require surface sediment in spawning areas high in gravel fractions and low in the finer sediment fractions. In 1994-1996 watershed restoration activities in the Pine Creek basin were undertaken to limit the supply of fine sediment reaching the stream system due to silvicultural land use activities, including road-building.

To assess the success of the restoration activities, the Hoopa Valley Tribal Fisheries Dept. conducted sediment surveys at riffles both before the restoration activities occurred, in 1992, 1993, and 1994, using a sampling design, measurement and laboratory techniques developed by Pacific Watershed Associates. Funding for that project was provided by an earlier grant agreement with USFWS, separate from this grant. Cross-sections at each sample reach were measured to attempt to detect changes in channel geometry. In 2000, sediment samples in the same reaches were collected to assess if any changes in the particle distribution had occurred. Shortly after the restoration activities were completed, a high intensity, low frequency rainstorm occurred. This "New Year's Day 1997" storm caused a flood of such magnitude that many cross-section pins and benchmarks were washed out. The results presented here, thus, cannot be attributed to restorations efforts alone, as the impact of the high intensity flood most likely dwarfed the short-term impacts of the restoration work.

**Study Sites**

Pine Creek watershed is a 49-square mile basin that drains the coast ranges of Northern California and discharges into the Klamath River at 2.4 miles downstream of the town of Weitchepec (Figure 1). Pine Creek's on-Reservation length is approximately 19.9 miles. The east side of Pine Creek is composed of 250 non-forested, 3,244 plantation, 900 original-sawlog, and 2,927 old-growth forest acres. West Pine Creek contains 9 non-forested, 3,140 plantation, 325 original-sawlog, and 2,017 old-growth forest acres. The Tribe completed a watershed assessment of the Pine Creek drainage in 1990 (Franklin, 1995). The watershed assessment identified limitations to salmonid production as a function of potential and actual sediment yield. Additionally, the assessment prioritized restoration objectives for the watershed. On-the-ground work has been completed in Little Pine Creek (funded by the Klamath River Task Force), with additional work completed in other portions of the sub-basin occurring within

## Figure 2: Water shed Restoration Sites, Pine Creek Watershed

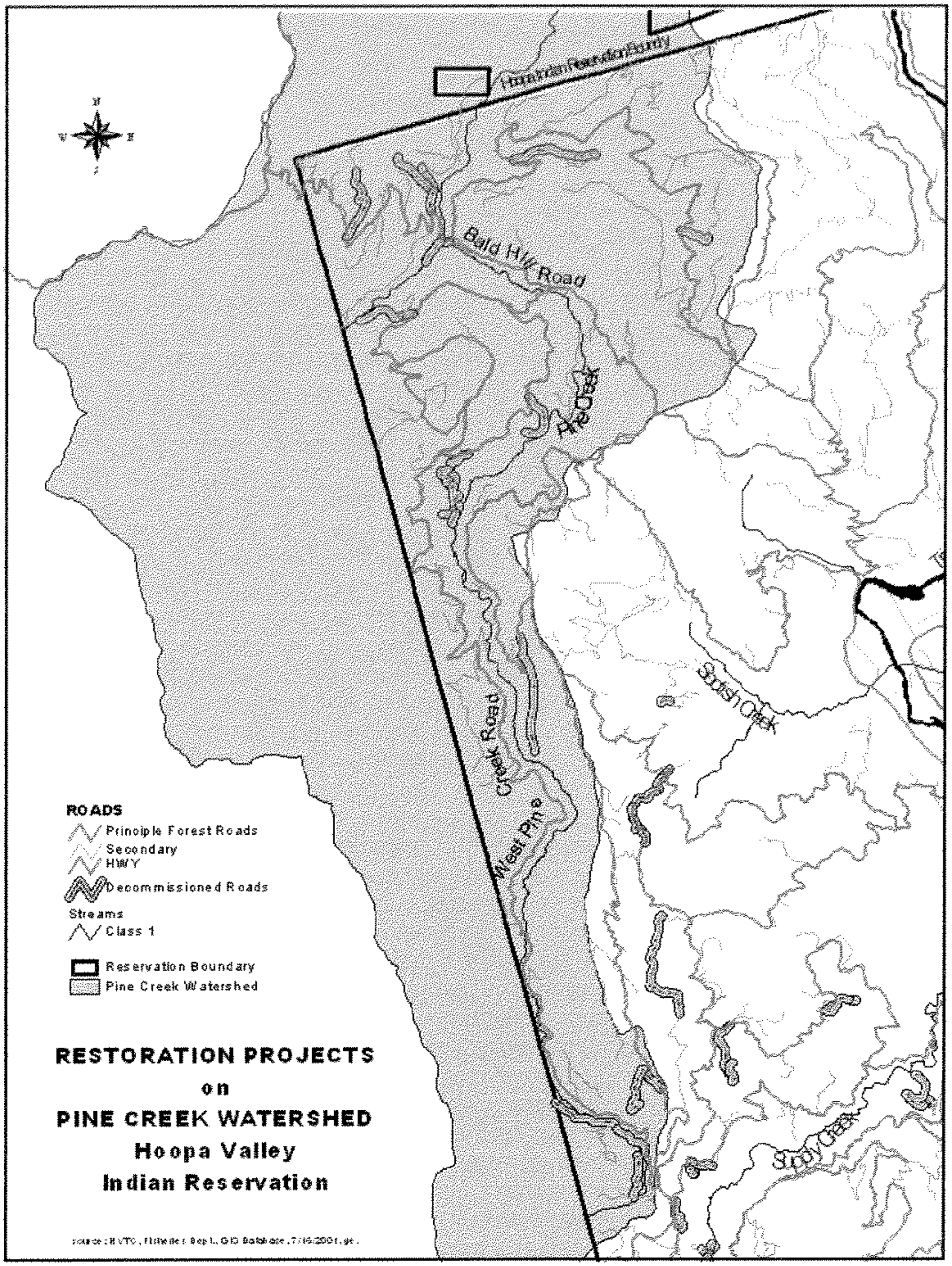
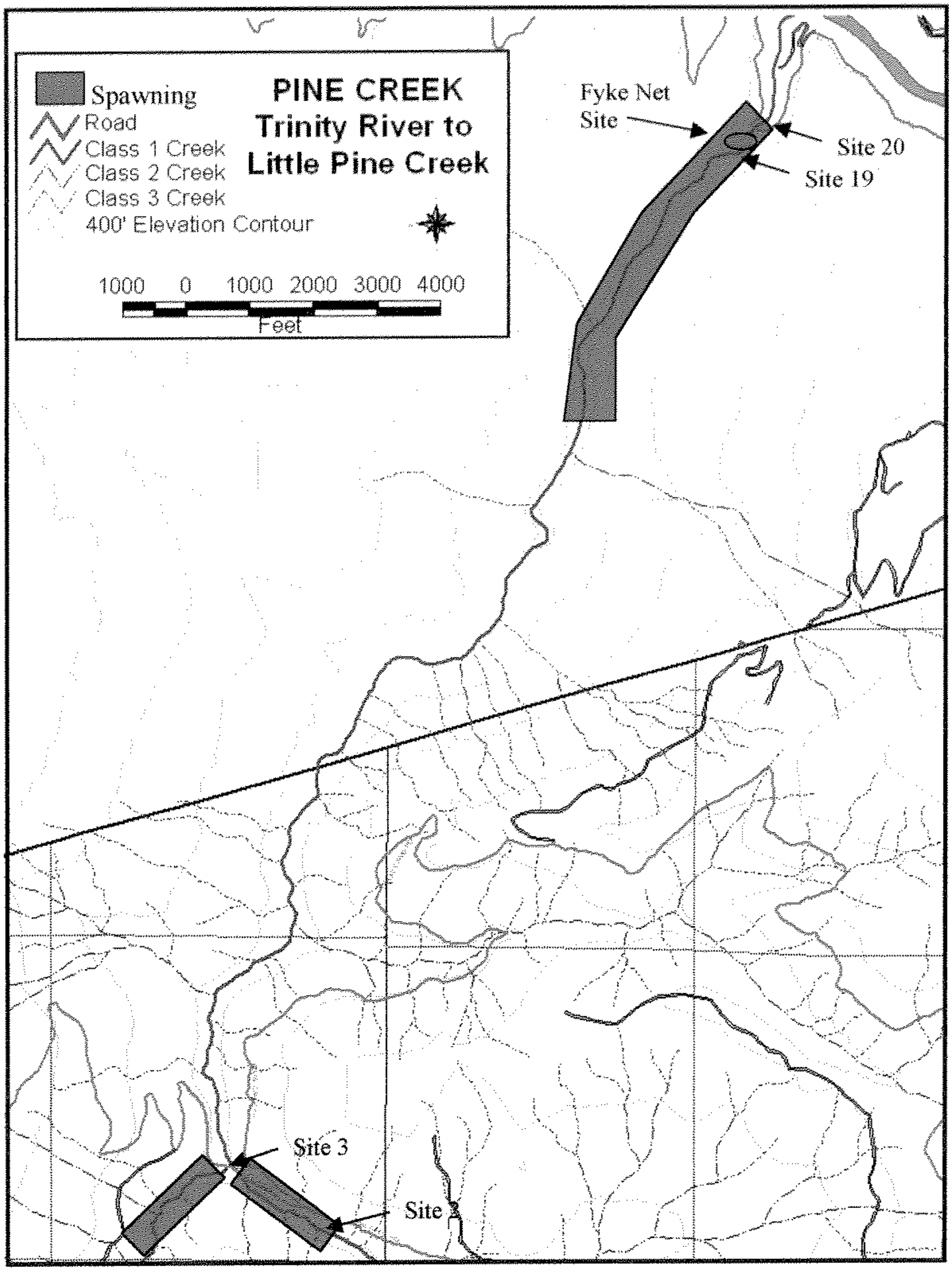


**Figure 3: Sample Locations**



the Hoopa Valley Reservation.

Restoration projects—composed of road decommissioning—are highlighted in Figure 2. Most of the road decommissioning (8 of 9.2 miles) was completed from 1994-1996. The balance of 1.2 miles was completed prior to 1992-1994. Pine Creek's watershed contained 90 miles of road prior to restoration activities (1992-1995) and 80.79 post-restoration (1996-2001). This resulted in a decreased road density from 4.49 to 4.03 mi/mi$^2$ (Table 1).

Four of the original eight sediment sampling sites from 1992 were sampled in 2000: sites 2, 3, 19, and 20. Figure 3 shows the location of these sites in the watershed. Sites 2 and 3 are higher in the watershed, upriver from the influence of the restoration work and thus represent the control sites.

**Table 1. Pine Creek watershed acreage (east section, west section, and total) with miles of total road per watershed, road density, miles of road decommissioned, and post-restoration road density.**

| Watershed | *Acreage* | Road System | | Miles Decommissioned | Post-restoration Road Density |
|---|---|---|---|---|---|
| | | Total Miles | Density (mi/mi$^2$) | | |
| **Pine East** | 7,325 | 47.06 | 4.11 | 3.25 | 3.83 |
| **Pine West** | 5,490 | 42.93 | 5.00 | 5.95 | 4.31 |
| **Total** | 12,815 | 89.99 | 4.49 | 9.20 | 4.03 |

## Methods

*Biological Investigations.* Although the habitat and fish sampling was originally scheduled for February-July 1996, high water conditions for a large portion of the sampling period made collections impossible. Instead, outmigrant sampling was conducted April-July 1996. Adult spawner surveys were conducted sporadically from December 1997 to April 1998. The data collected in 1996 were grouped with other post-restoration data that was collected using consistent methodology (described below). Although the sampling season may have differed among years, the methodology did not vary. The post-restoration data set for years 1996-2001 was compared to data collected prior to completion of restoration activities (1992-1995).

Juvenile monitoring was achieved by the operation of two fyke traps located within the lower stream mile of the Pine Creek drainage. The trap mouth consisted of a steel 5' x 5' frame flowing into a single mesh throat (forward 10' of mesh 3/8" x 5/8" [#9038]; aft 10' of mesh ¼" delta [#8635B]; total length 20'). Corner and mouth seams were reinforced with 1" nylon seam tape and hand-hung to support ropes (3/8" polypropylene). Zippers (3' long) on each side of the trap throat were located in the aft end of top and bottom panels. The nets were flat-bottomed, sloped from the top only (with the cod end designed to cinch to a 6-5/8" diameter pipe), and were treated with flexdip net treatment (Research Nets, Inc. Bothell, WA 425-821-7345). A heavy piece of rectangular vinyl was placed between the net and substrate; its grommeted edge was lashed to the trap mouth to avoid net chafing.

Fyke traps were installed in April 1996 and remained in place for daily sampling, four trap-net nights per week, through mid-July. Beginning and end dates for trap installation and removal varied depending on hydrologic characteristics (flow regime) and outmigration rates for years other than 1996. Captured juveniles were categorized with respect to species. Length (fork length, mm) was recorded from a sub-sample of 25 fish per species. The data were used as an index to reference changes through time in Pine Creek as a function of relative abundance (catch per day). F-tests were conducted to detect differences in variances between pre- and post-restoration time periods. T-tests (2-tailed) were conducted to test the null hypothesis that pre- and post-restoration CPUE was not different for a particular species. Linear regression was performed (CPUE vs. year for each species) for pre-and post-restoration catch data to discern trends in either dataset. Alpha levels of 0.05 were used for all statistical tests. No extrapolation to absolute abundance from this data was made, as trap efficiency was unknown.

Two-person crews conducted adult spawner escapement estimates. Data were collected in several index reaches. Ocular estimates of redd location, size, substrate, and habitat types were documented according to methodology adopted by Six Rivers National Forest (Overton, *et* al. 1997). These data were used to calculate number of redds per sample year, average redd size, estimated escapement (number of redds multiplied by 2.25), average substrate composition, and preferred spawning-habitat type. The mulitplier value of 2.25 is based on the assumption that two fish successfully spawned--and 0.25 fish may have migrated but not successfully spawned--for each redd observed. The 0.25 addition to the direct relationship of two fish per redd more accurately accounts for fish or redds that were overlooked during the surveys. Redds were attributed to a specific species where fish were identified on the redds or where month of survey afforded reasonable confidence in doing so. All redds documented in mid-January and later were attributed to steelhead; steelhead would likely be the only species constructing a new redd at that time of year (Trinity River Mainstem Fishery Restoration EIS, 1999). All redds prior to mid-January were attributed to salmon.

Spawner survey data were only used qualitatively as sampling bias (intra- and inter-annual variation in sampling duration, location, and timing) prevented quantitative comparisons. Also, no spawner survey data for the pre-restoration period was on file; pre- and post-restoration periods with respect to redd abundance could not be compared.

Fyke net and spawner survey reaches are shown in Figure 3.

*Sediment Investigations.* The sediment portion of the 1996 grant agreement called for the V-star technique to measure fine sediment in pools. The selection of field technique was changed to volumetric particle size distribution (McNeil & Ahnell, 1960) for the following reason. In the original USFWS agreement for the 1992-1994 work, volumetric particle size distribution was used to determine spawning sediment quality. Though V-star gives valuable information about the assessment of existing watershed health, it will not give any information about a comparison of that health with previous watershed conditions. The "Program Information" section of the existing grant agreement (14-48-0001-96) states that the intent of this monitoring program is "…to gather evidence relative to the efficacy of prescribed land treatments in restoring usable habitat for steelhead and other anadromous species within the Pine Creek watershed." To make the pre-treatment and post-treatment results comparable, the same sampling techniques and protocols must be used.

Sediment was collected with a McNeil sediment sampler. Four replicate samples were taken in each sampling reach, the reach boundaries were matched to the 1992-94 reach boundaries. The location of each sample was chosen randomly using the same random number method used in 1992-94. In this scheme random numbers are used to determine the length from the upstream end of the reach and the percent distance from left to right bank. Samples are then wet-sieved in the laboratory and volumes are measured through volumetric displacement in water, using the method described by McNeil (1963). Fractions are then analyzed and graphed in Microsoft Excel. The sieve sizes, as "size retained by the sieve" used here are: 124, 90, 63.5, 31.5, 12, 4, 1, 0.5, and 0.125 mm. Material that passed the 0.125mm sieve were collected and settled in Imhoff cones. These size fractions were chosen to match the sampling procedures used in the 1992-94 efforts. For the purpose of analysis, fine sediment is defined here as anything smaller than gravel, in this case, sediment smaller than 12mm mean particle diameter.

To test among the replicate samples in one year, a one factor analysis of variance (ANOVA) was conducted. A test was performed for both 1994 and for 2000. In these ANOVA results, each group is one site. To satisfy the requirement for ANOVA that the variances are homogenous, or equal, within the level of significance, Bartlett's test was used. The F-test is a more common test, but is appropriate only when there are two sample means. Bartlett's test is appropriate with more than two sample means. The formula used here is a standard one, see Ponce (1980, p. 56-57) and Sokal and Rohlf (1981, pp 405-407) for specifics. The statistic calculated with Bartlett's test is a chi-square, which is compared against the critical chi-square value. If the critical chi-square is the greater of the two, we accept the null hypothesis that the variances of the sample means are homogenous. For a test of two means, a Student's t-test was used. T-test calculations were performed in the data analysis package in Microsoft Excel, 1997.The significance level used in both the ANOVA and t-tests is =0.05. The t-test was used to compare the same site between the two years. If the calculated t-value is less than the critical t-value then we must accept the hypothesis that over time the means are from the same population. Stated differently, if the underlying sediment distribution over time does not change, then we expect the fine sediment fraction to be the same, and the student's T to be less than the critical t-value.

**Results and Discussion**

*Biological Investigations.* Coho were found in the lowest overall relative abundance; no coho were captured in several sample seasons at all. Chinook ranked next, then steelhead at the highest relative density. These values and the average catch per day for the entire 1992-2001 period are displayed in Table 2 and graphically in Figure 4.

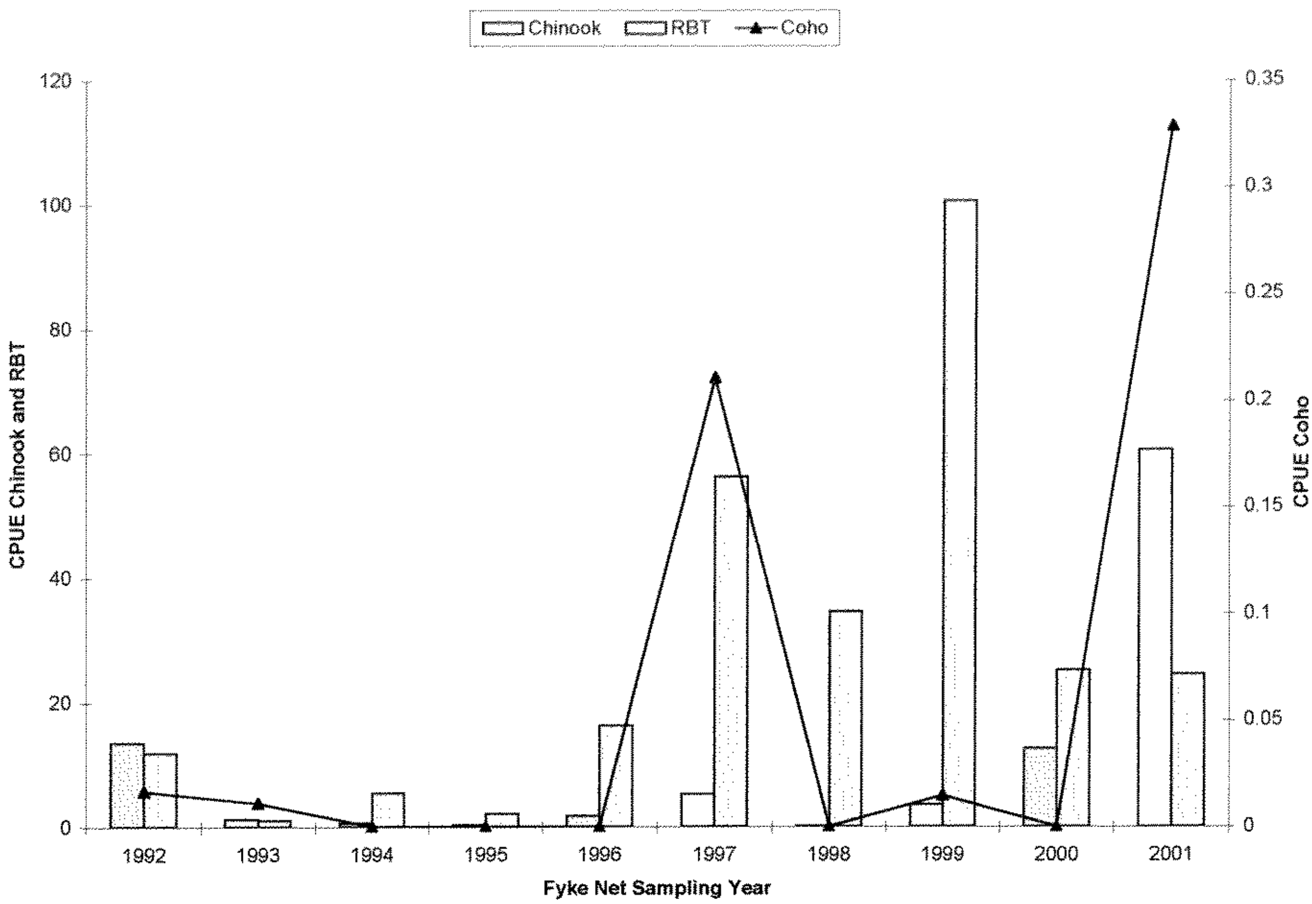
**Table 2.—Average catch per unit effort (catch per day) for four years of fyke-net sampling on Pine Creek (C.I. = Confidence Interval)**

| | Chinook | Steelhead | Coho |
|---|---|---|---|
| 1992 | 13.5 | 11.9 | 0.02 |
| 1993 | 1.3 | 1.1 | 0.01 |
| 1994 | 0.7 | 5.4 | 0.00 |
| 1995 | 0.3 | 2.1 | 0.00 |
| 4-year avg + C.I. (C.I.=95%) | 3.9 + 10.2 | 5.1+7.8 | 0.01 + 0.01 |
| 1996 | 1.8 | 16.3 | 0.0 |
| 1997 | 5.3 | 56.3 | 0.2 |
| 1998 | 0.1 | 34.6 | 0.0 |
| 1999 | 3.6 | 100.7 | 0.0 |
| 2000 | 12.6 | 25.2 | 0.0 |
| 2001 | 60.7 | 24.5 | 0.3 |
| 6-year avg + C.I. (C.I.=95%) | 14.0+24.4 | 42.9+33.0 | 0.09+0.15 |

**Table 3-Number of identified redds per year (Fall to Winter sampling season) in Pine Creek 1997-2000.**

| Year | Fall '97-Winter '98 | 1998-1999 | 1999-2000 | 2000-2001 |
|---|---|---|---|---|
| Redd Count | 17 | 1 | 0 | 14 |
| Est. Escapement | 38 | 2 | 0 | 32 |
| # Days Sampled | 6 | 1 | 2 | 6 |

**Figure 4.—Catch per unit effort (catch per day) versus year for three anadromous stocks of Pine Creek. "Year" is spring-summer sampling season.**




Steelhead redds comprised 67% of those documented, as determined by fish present on the redd or month of documentation. The average redd size was 28.52 $ft^2$ at an average depth of 1.19 ft. The average substrate composition was 19% sand, 38% gravel, 39% cobble, and 5% boulder. The preferred habitat type was *Run*. Redds identified during spawning surveys are tabulated in Table 3.

Spawner survey results were variable, largely due to sampling design and subjectivity implicit to this type of survey. Spawning surveys are largely weather-dependent and rely upon direct observation by a trained eye. Also, the data did not exist pre-restoration for redd abundances during that period.

Six other anadromous fish-bearing streams exist on the Hoopa Reservation. Never has a catch-per-day exceeded 0.50 for coho in these streams (Hoopa Valley Tribal

Fisheries, unpublished data). This would seem to support the assumption that fyke net sampling is occurring in proportion to population abundances. Simply put, however, coho are extremely infrequent in Pine Creek (and other sampled tributaries). It is reasonable to assume, then, that coho abundances in 1996 seem to be reflective of their listed threatened status.

Another explanation for low coho numbers is that Pine Creek is a flashy, high-gradient stream with relatively large substrate. One might expect that coho juveniles would be scarce in Pine Creek, as coho typically seek areas with side channels, sloughs, and even beaver ponds to overwinter as juveniles, and small tributaries in which to spawn (Meehan 1991). Embryos in coho redds remain overwinter and may be disturbed by the freshets and flashy hydrograph of Pine Creek.

Relative to steelhead, chinook generally seek deeper water, are less tolerant of high velocities for spawning, have lower jumping distances, and prefer several more square meters of substrate in which to construct redds (Meehan, 1991). The hydrology and morphology of Pine Creek would select against a fish with most of these qualities. Although chinook spawning is obviously occurring in Pine Creek, it is likely that Pine Creek offers steelhead more spawning opportunity (suitable habitat) than it offers to chinook. Pine Creek's hydrology or morphology, which conflict with the chinook's habitat preferences, may have always limited Chinook spawning. As such, chinook may not be a good indicator species for decreased sedimentation and watershed restoration effects on available, <u>suitable</u> habitat (as measured by outmigrants).

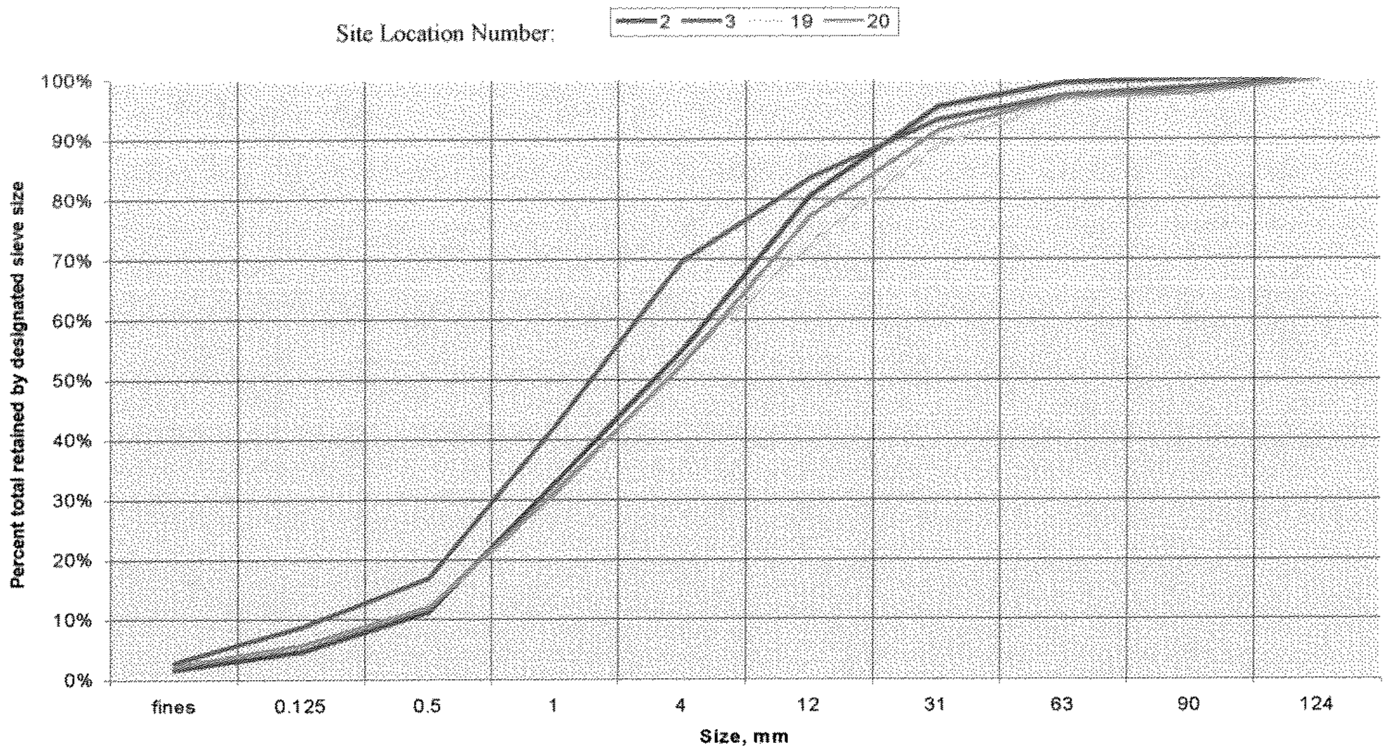
Pine Creek seems to provide habitat favorable to steelhead with a relative abundance of steelhead to chinook at roughly 3 to 1 for the entire 1992-2001 period. Sixty-seven percent of the redds observed from 1997-2000 were in the month of February or later. Life history characteristics of coho, chinook, and steelhead deductively link steelhead to these redds; other fish are rarely still spawning in February (Trinity River Mainstem Fishery Restoration EIS, 1999). The relative abundance of redds, outmigrating juveniles, and the post-restoration increase in outmigrants indicates that habitat in Pine Creek favors steelhead. The data also indicate that the steelhead population in Pine Creek was responsive to restoration efforts, as measured in juvenile outmigrants.

*Sediment Investigations.* Site 19 and 20 are downriver from the watershed restoration activities and thus represent the treatment areas. Figures 5 and 6 show the cumulative sediment graphs of each site for 1994 and 2000, respectively. The variability at the sites is more easily assessed from bar charts showing the percentages in each of the size fractions. These graphs are presented in Figures 7 and 8.

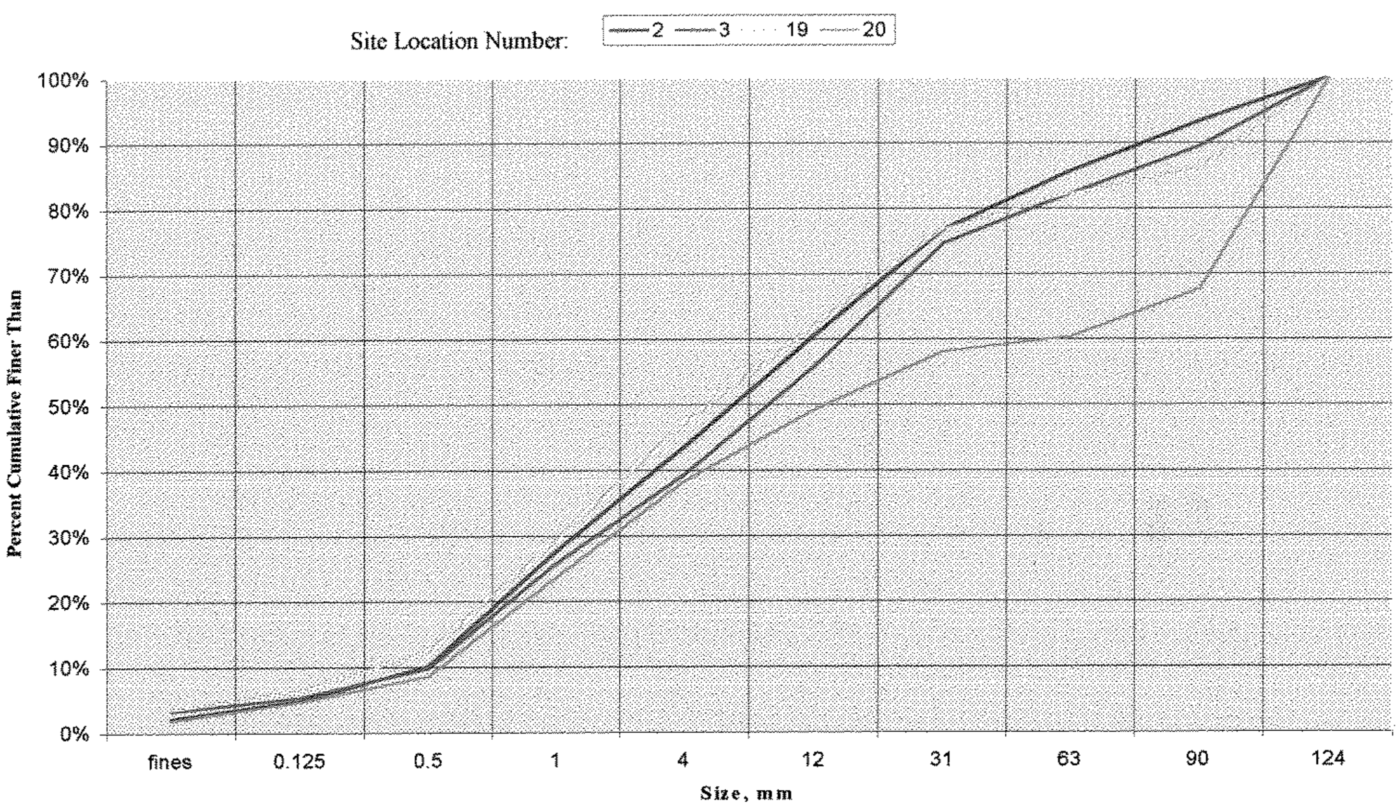
A visual inspection of the two graphs shows that there is little variability in the fine sediment among sites in both 1994 and 2000. In these samples, the fines fraction is that which passes through the 4mm sieve. In the graphs it is shown as sediment retained by the 1mm sieve (the next size smaller than 4mm). There is far more variability among sites in the cobble fractions, defined as 76mm or higher. In the graphs cobbles are indicated in the 90mm+ and 124mm+ bars.

The mean percentage of fine sediment decreased at all sites, both control and treatment, from 1994 to 2000, indicating a general increase in the quality of surface material as spawning gravel in riffles and pool tail crests in Pine Creek. This is depicted in the first line of Table 6, where the decrease in cumulative percent fines ranges from the most subtle 4.7% in site 19, a treatment site, to 11.1%, the other treatment site. The variance increased at three of the four sites, indicating increased variability, or heterogeneity of surface substrate composition. At site 2, the variability decreased substantially, indicating less variance. The two control sites, 2 and 3, experienced the greatest absolute change in variance, suggesting that the variability in the fraction of sediment in the treatment sites has changed less than at the control sites. Variability in storm hydrographs tends to increase "up-watershed", exhibiting a "flashy" character. Because sediment movement is function of magnitude and duration of flow, sediment variability may well be higher "up-watershed." The magnitude of the 1997 flood may thus have contributed to the increased absolute variability in fine sediment in the control sites.

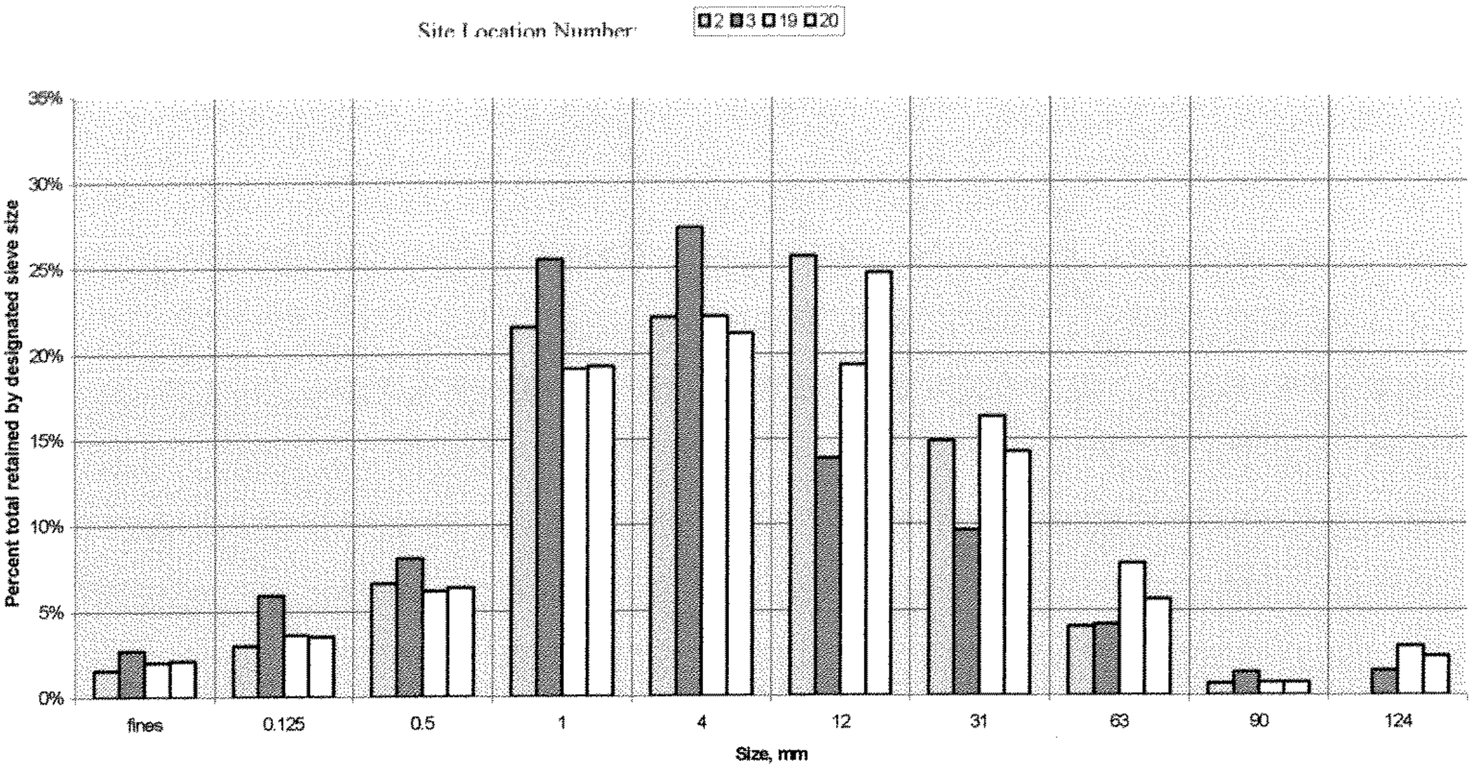
# Figure 5: 1994 Pine Creek Sediment Distribution




# Figure 6: 2000 Pine Creek Sediment Distribution



# Figure 7: 1994 Pine Creek Sediment Distribution




# Figure 8: 2000 Pine Creek Sediment Distribution

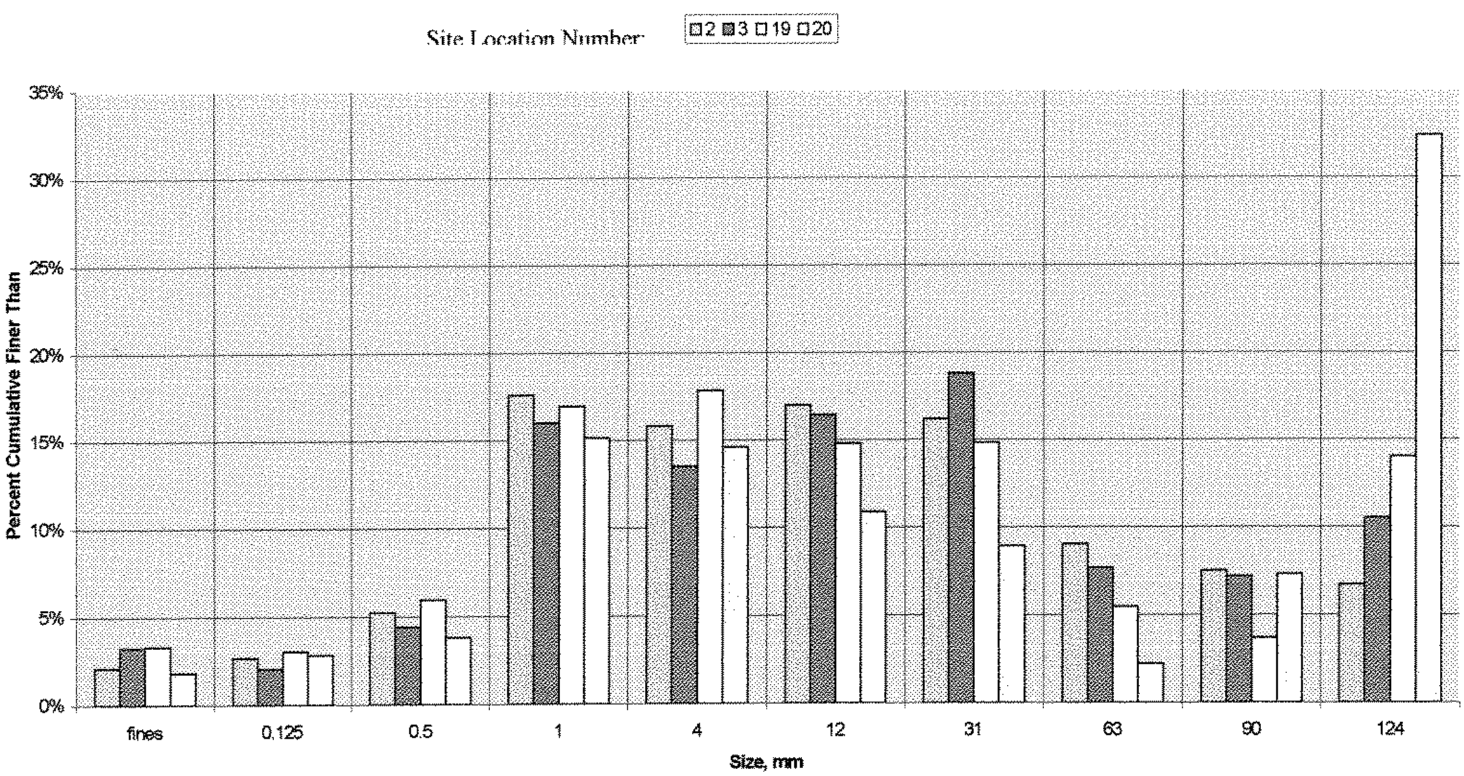


**Table 4: 2000 Cumulative Percent Fine Sediment up to 4 mm Diameter**

| Site --> | Site 2 | Site 3 | Site 19 | Site 20 |
|---|---|---|---|---|
| Sample 1 | 24.3% | 26.6% | 31.0% | 15.0% |
| Sample 2 | 28.2% | 28.3% | 25.2% | 24.5% |
| Sample 3 | 21.3% | 25.9% | 34.9% | 21.9% |
| Sample 4 | 36.1% | 20.0% | 26.1% | 30.2% |
| | | | | |
| Mean | 27.5% | 25.2% | 29.3% | 22.9% |
| Variance | 0.41% | 0.13% | 0.20% | 0.40% |
| Std Deviation | 6.4% | 3.6% | 4.5% | 6.3% |

**Table 5: 1994 Cumulative Percent Fine Sediment up to 4 mm Diameter**

| Site --> | Site 2 | Site 3 | Site 19 | Site 20 |
|---|---|---|---|---|
| Sample 1 | 28.9% | 36.5% | 35.6% | 32.0% |
| Sample 2 | 37.2% | 62.6% | 33.9% | 28.0% |
| Sample 3 | 35.1% | 35.4% | 22.4% | 40.4% |
| Sample 4 | 34.5% | 37.8% | 32.1% | 22.7% |
| | | | | |
| Mean | 33.9% | 43.1% | 31.0% | 30.8% |
| Variance | 0.12% | 1.70% | 0.35% | 0.56% |
| Std Deviation | 3.5% | 13.0% | 5.9% | 7.5% |

**Table 6: Change in Cumulative Percent Fine Sediment, 1994 to 2000**

| Site --> | Site 2 | Site 3 | Site 19 | Site 20 |
|---|---|---|---|---|
| %decrease in mean | 6.5% | 8.7% | 4.7% | 11.1% |
| %increase in variance | -229% | 92% | 42% | 29% |

To make a more rigorous determination of changes, we now consider whether or not these trends are significant. The significance level used is here is alpha=0.5. Two questions and hypotheses, one spatial, and one temporal, are tested here. The first, a spatial hypothesis, is "there is no difference between the means of the samples taken before the restoration." This hypothesis is also repeated for the post-project samples. This helps us to answer the question "was there any difference in the control and planned treatment sites in the pre-project phase." If we then ask the same question about the post-project sites we can determine if there is any significant variation between all the sites in a given year, either pre-project or post-project. If we find a significant difference, we can then test the means individually to determine where the significant difference exists.

To test the first hypothesis, $H_0$: $_{2}= {}_{3}= {}_{19}= {}_{20}$, we conduct a one factor analysis of variance (ANOVA) for 1994 samples. Several prerequisites, or assumptions, must be satisfied before performing an ANOVA. The first is that the samples are random and independent. The random sampling scheme used is described in the "Methods" section and we assume independence as a by-product of the randomness of the sampling. Second, the variances be homogenous, or equal, within the level of significance. In a test with more than two sample means, Bartlett's test is used. Results show that the variances of all sample means considered together are homogenous. This is true for both 1994 and 2000.

**Table 7: Bartlett's Test for Homogeneity of Variances**

| Year | 2 - sample | 2 - critical | Accept/Reject $H_0$ |
|---|---|---|---|
| 1994 | 4.97 | 7.82 | Accept |
| 2000 | 1.27 | 7..82 | Accept |

**Table 8: One factor ANOVA, Percent Cumulative Fine Sediment, 1994**

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 0.039855 | 3 | 0.013285 | 1.942237 | 0.176671 | 3.4903 |
| Within Groups | 0.082082 | 12 | 0.006840 | | | |
| | | | | | | |
| Total | 0.121937 | 15 | | | | |

Because our calculated F-value, 1.94, is less than the critical F-value, 3.49, we accept the null hypothesis. This we can state that at the 0.05 level of significance that there was no difference in the percentage of fine sediment at any of the four sites in 1994. This leads to the conclusion that in the pre-project scenario there was no difference between the fine sediment fraction of the surface sediment between control and treatment sites.

**Table 9: One factor ANOVA, Percent Cumulative Fine Sediment, 2000**

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 0.009249 | 3 | 0.003083 | 1.078972 | 0.394899578 | 3.4903 |
| Within Groups | 0.034287 | 12 | 0.002857 | | | |
| | | | | | | |
| Total | 0.043536 | 15 | | | | |

The calculated F-value, 1.07, likewise, is less than the critical F-value of 3.49 in 2000. Once again we must accept the null hypothesis and state that at the 0.05 level of significance that there was no difference in the percentage of fine sediment at any of the four sites in 2000. Again in 2000, we deduce from these results that there was no difference in control plots relative to the treatment plots either in 2000.

Sediment changes in river systems tend to be subtle over short periods of time, absent a catastrophic event, such as a 100-year flood, or a change in chronic fine sediment inputs, such as contributed by management practices, such as roads, timber harvest, grazing, mining.

The second hypothesis, a temporal one, gets at the question "is there any change between the control sites and the treatment sites over time." Stated otherwise, "have the restoration projects resulted in a net benefit to quality of the spawning gravel?" The hypothesis here is that there is no difference between the means of at each site between the pre-project and the post-project data.

The first test, a standard used in many scientific publications, is to use the standard error as confidence limits about the sample mean (Sokal & Rohlf, 1981). If we use a hypothesis that $H_0$: $_{1994} = {}_{2000}$ at each site within a confidence interval bounded by the standard error of the 1994 (pre-project) data, then we reject $H_0$ for all four sites.

**Table 10: Change in fine sediment between 1994 and 2000**

| | #2 (control) | #3 (control) | #19 (treatment) | #20 (treatment) |
|---|---|---|---|---|
| 1994 ±SE | .339±.035 | .431±.130 | .310±.059 | .308±0.075 |
| 2000 | .275 | .252 | .261 | .229 |
| $H_0$ | Reject | Reject | Reject | Reject |

We thus conclude that the decrease in mean percentage of fine sediment sampled at each site is significant at a confidence level of one standard error. If this change was caused by the restoration efforts we would expect to see a difference between the change at the control sites and a difference in the change at the treatment site. It is likely that watershed processes affecting the entire watershed is responsible. One possibility, mentioned earlier, is a "flushing effect" of the fine sediment caused by the 1997 flood. Future sampling at the same sites could help determine whether there is any change in the long-term sediment inputs, such as those intended to be remedied by the restoration efforts.

To determine the difference in the significance at each of the four sites over time we use a t-test, using four t-tests, one for each site over time. The critical t-value was 3.182, and the Student's t-value for sites 2,3,19, and 20, respectively, were 0.1415, 0.0670, 0.6624, and 0.1582. The results indicate that we must accept the hypothesis that the means at 1994 and 2000 are equivalent for each of the four sites. Thus as we increase our confidence level from one standard error (Table 10) to two standard errors (a t-test with =0.05), the pre-treatment means and post-treatment means for all sites change from being significant to being not significant. However, the two treatments sites do not exhibit a trend separate from the two control sites. The conclusion we draw from this is that there is a significant decrease of fine sediment in the sites sampled (at a level of one standard error), but this decrease cannot be attributed to the effects of watershed restoration efforts.

**Summary and conclusions**

The significant post-restoration increase in steelhead population indicates that restoration efforts were an important contributor to this increase, though the physical channel changes resulting from the 1997 flood were also likely an important factor. For the opposite of reasons outlined for coho and chinook, steelhead should serve as a Pine Creek stock sensitive to watershed restoration. With its increased tolerance of shallower, faster water with larger substrate for spawning, as well as its documented higher swimming and jumping speeds (Meehan 1991), steelhead would have accessed more of the restored creek. Additionally, steelhead—with broader bounds on suitable spawning habitat—would have found more areas suitable for spawning had they been only marginally restored. Regression analysis did not reveal an upward trend in steelhead abundance, but this would be expected if the chronic sediment problems pre-1996 were gradually decreased. Then, in 1996, abnormally high flushing flows cleared embedded substrate. Without the chronic sediment problem immediately burying new habitat, one would expect to see a sudden jump in spawning success (CPUE) rather than a gradual trend. This is, indeed, what is observed in regression analysis and supported by the t-tests (Table 7).

Therefore, Pine Creek holds and produces anadromous fish stocks. The most abundant of these are steelhead, which can be found at orders of magnitude higher relative abundance than other anadromous species. This indicates a variable, but increasing Pine Creek steelhead stock. The presence of favorable conditions is supported by a stable age-0 chinook stock. The chinook stock is likely limited by hydrologic and morphologic factors and, as such, is an inappropriate indicator of the success of these restoration efforts.

Current literature also advises that endangered or rare species do not make adequate indicators of change (Kohler and Hubert, 1993). When looking to steelhead as the default indicator species, it is evident that the CPUE has increased from pre- to post-restoration. This is likely due to the fortunate timing of restoration efforts and flushing, floodwater flows of 1996.

High inter-year variability masks, or at least dampens, any existing relationship between restoration efforts and anadromous fish abundance. Pine Creek steelhead were the only stock displaying an increased relative abundance in the post-restoration period. More years of data collection are necessary to more accurately determine trends. Further research should focus on mark-recapture experiments to extrapolate indices to population abundance estimates, as well as comparisons to other on- and off-Reservation tributary production in similar watersheds. What is certain is that the restoration efforts were not detrimental to the Pine Creek stocks of concern, and these stocks likely benefited from restoration actions in the watershed.

As mentioned, Pine Creek is a flashy stream, having steep side slopes and many high-gradient reaches. For that reason, the 1996 survey season in Pine Creek was truncated due to dangerous conditions. The extended years of data discussed above have been provided to supplement and buttress the dataset which was abbreviated due to high water levels.

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**Fulfillment of Grant Objectives**

Modification of the Milestones as outlined in the Grant Agreement was necessary due to dangerous conditions and conditions of low-visibility in 1996. The major objectives of the Grant Agreement have been met, namely:

Task 1) Juvenile monitoring: conduct in-stream sampling to index the abundance of juvenile salmonids within the Pine Creek watershed

Task 2) Adult escapement monitoring: conduct periodic spawner redd surveys in index reaches of Pine Creek

Task 3) Habitat quality monitoring: conduct a sediment recruitment survey.